Predictability of the Normalized Difference Vegetation Index in Kenya and Potential Applications as an Indicator of Rift Valley Fever Outbreaks in the Greater Horn of Africa

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ABSTRACT

In this paper the progress made in producing predictions of the Normalized Difference Vegetation Index (NDVI) over Kenya in the Greater Horn of Africa (GHA) for the October–December (OND) season is discussed. Several studies have identified a statistically significant relationship between rainfall and NDVI in the region. Predictability of seasonal rainfall by global climate models (GCMs) during the OND season over the GHA has also been established as being among the best in the world. Information was extracted from GCM seasonal prediction output using statistical transformations. The extracted information was then used in the prediction of NDVI. NDVI is a key variable for management of various climate-sensitive problems. For example, it has been shown to have the potential to predict environmental conditions associated with Rift Valley Fever (RVF) viral activity and this is referred to throughout the paper as a motivation for the study. RVF affects humans and livestock and is particularly economically important in the GHA. The establishment of predictability for NDVI in this paper is therefore part of a methodology that could ultimately generate information useful for managing RVF in livestock in the GHA. It has been shown that NDVI can be predicted skillfully over the GHA with a 2–3-month lead time. Such information is crucial for tailoring forecast information to support RVF monitoring and prediction over the region, as well as many other potential applications (e.g., livestock forage estimation). More generally, the Famine Early Warning System (FEWS), a project of the U.S. Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA) and other specialized technical centers routinely use NDVI images to monitor environmental conditions worldwide. The high predictability for NDVI established in this paper could therefore supplement the routine monitoring of environmental conditions for a wide range of applications.

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1. Introduction

The initial motivation for the current investigation of Normalized Difference Vegetation Index (NDVI) predictability is its potential for contributing to the stabilization of the livestock trade between the Greater Horn of Africa (GHA) and the Middle East. Cases of Rift Valley Fever (RVF), a vector-borne disease, have been reported in parts of Africa since the 1950s (Davies et al. 1985; Swanepoel 1981). The disease was first identified in Kenya in 1931, when a target flock of exotic sheep kept in the Rift Valley suffered severe losses. The RVF virus is transmitted by mosquitoes of the genus *Aedes*, which breed in flooded low-lying habitats known as dambos (Meegan and Bailey 1989). Dambo depressions are common in many parts of Africa (Davies et al. 1985). RVF causes epizootics (large-scale transmission) in domestic animals and epidemics in human populations closely associated with infected animals. Outbreaks of RVF in recent years have been accompanied by bans on livestock trade between the GHA and the Middle East. RVF outbreaks and trade bans since the 1997/98 El Niño event have cost the GHA \$300–\$500 million annually [Organization of African Union/Inter-African Bureau of Animal Resources (OAU/IBAR) 2003, personal communication). Livestock accounts for a significant percentage of the gross domestic product (GDP) in many GHA countries. RVF-related trade stoppages have had severely detrimental impacts on livelihoods of many pastoralists.

Outbreaks of RVF in Africa are characterized by distinct spatial and temporal patterns that are directly related to specific environmental parameters associated with mosquito vectors. Depending on their status, environmental variables such as vegetation, soil moisture, and temperature, maintain endemic levels of the virus and/or promote epizootic level of transmission (Linthicum et al. 1990). The NDVI is a measure of vegetation greenness and is a good proxy for rainfall and soil moisture (Tucker 1979; Tucker et al. 1986).

RVF disease has been reported in Kenya at intervals of 3–12 yr, mostly in the Eastern and Western Highland plateau areas at the coast. Outbreaks were reported in the years 1951–53, 1961–63, 1967/68, 1977–79, 1982/83, and 1997/98 (Davies et al. 1985; Linthicum et al. 1999). The most recent major outbreak during late 1997 to early 1998 has been linked to the heavy and prolonged rains associated with El Niño–Southern Oscillation (ENSO; Trenberth 1998; Linthicum et al. 1999). Most reported cases during this period were confined to the semiarid zones in the north and northeast of Kenya, similar to the 1961/62 episode.

6. Conclusions

Statistical transformation procedures have been applied to the output from global climate model (GCM) seasonal predictions, in order to derive prediction information that more closely matches the needs of a societal problem. The methodology is based on the premise that climate variability, and especially precipitation, drive substantial variability in NDVI, which is a key indicator for the management of a range of environmentally related social problems. One such problem that has been identified is livestock Rift Valley Fever (RVF) and its effects on pastoral livelihoods both directly and through trade implications. Demonstration of our ability to predict seasonal precipitation variability with good skill, and then "downscale" it into high-resolution NDVI information, suggests a reliable scheme for predicting the risk of RVF outbreaks a few months in advance is feasible across much of this region, at least to the extent that RVF is linked to NDVI.

NDVI is highly dependent on soil moisture conditions, and precipitation fields from the GCM were expected to provide a good proxy. NDVI is also dependent on other factors that include soil type, elevation, etc., which may induce a varying responses of NDVI to climate forcing. The approach of applying a statistical transformation to the output of the GCM to fit it to NDVI variability provides an empirical methodology that factors in these complexities.

In the absence soil moisture data, NDVI has been used to monitor RVF episodes over the GHA. We have demonstrated from this study that NDVI can be skillfully predicted with a 2–3-month lead time using GCM forecasts of regional rainfall and circulation patterns. Our results show good skill for NDVI over most parts of Kenya, decreasing in the highland areas.

Results were initially derived using GCM simulations with observed SST. When the GCM is run mimicking a true operational forecast situation (i.e., using persisted September SSTAs) skill declines only marginally as shown in Fig. 11. For an NDVI index in northeast Kenya, correlation skill falls marginally from 0.82 to 0.76. These results are based on a sample of 17 yr. The climate predictability for the region has been demonstrated over a much larger set of years and is considered robust. It will be useful to extend the analysis with NDVI over recent years to continue to increase the robustness of this part of the forecast system.

Although RVF cases have been reported both over the Kenya highlands as well as the lowlands, our analysis has shown better NDVI predictive skill over the lowlands, suggesting at this stage, higher confidence is expected in predicting RVF outbreaks over the lowlands of Kenya and Tanzania. These results provide potentially useful information for factoring in the detection and monitoring of suitable conditions for RVF outbreaks, and developing strategies for mosquito control and disease prevention. An early warning system could be tailored to provide guidance on the remedies to be taken including vaccination of the animals, stabilizing the movement of the animals, and mosquito control measures such as treating of the mosquito-breeding dambos.